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Exploring the levels of availability and access to open/green space and health outcomes

The case of Camden, London

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ABSTRACT

Green spaces and open spaces, can be a source for network formation and strengthening. This can impact social conditions and therefore influence well-being through knowing friends, making acquaintances and belonging to a larger group that could help with loneliness, isolation and other mental health aspects. Walking is unnoticed in large area models of urban behaviour since it is a common perception of cities being well connected through vehicular movement and accessibility. Neighbourhoods have access to leisure amenities through pedestrian paths around parks, and there are many social influences that prompt a resident to use spaces like cafes, bookstores, shops around open-green spaces. These areas have a combination of social housing units and self-reported health levels. How do we understand the use and access to open-green spaces around regions that have different health levels?

Camden, in the heart of London, is a popular and well-facilitated area that has been established by the local council. This area has been a catalyst for development because of its unique spatial position. The parks within Camden have been visibly transformed, however, the extent of usage around the social housing and areas with poor health is unclear. This research focuses on mapping health and its variables and access to green spaces, main areas of high deprivation or other specific variables that are likely to contribute to ill health, particularly in the regions of social housing estates in Camden exploring the problems with access to green parks using Space syntax methods. It also compares the syntactic values of having a small local park within the neighbourhood, as opposed to a larger metropolitan park, outside the neighbourhood but within the borough.

KEYWORDS

Mapping health levels, Spatial access, Open and green space availability, social housing, social infrastructure

1 INTRODUCTION

1.1 PARKS AND URBAN HEALTH

Hugh Cunningham (1780-c. 1880) notes that from the late-1820s, the leisure-patterns of the wealthier parts of society were considered by some social reformers as a solution to urban problems. The lack of opportunities afforded to the majority of urban citizens, rational recreation would provide social, educational, health and moral improvement which caused the need to improve the non-working urban experience became an important part of social discourse and wellbeing in the 1830s (Cunningham 1830).

Today, Urban green spaces, such as gardens, play area, and suburban greenery, can endorse physical and mental health, and reduce sickness and death in urban inhabitants by providing mental relaxation and motivating social unity, stress easing, supporting exercise, and reducing contact to air pollution, noise and extreme heat (Takano et al. 2002). Urban green space can include publicly accessible areas with natural vegetation, such as grass, plants or trees [and may include] built environment features, such as urban parks while suburban areas less managed areas, including woodland and nature reserves tend to be found outside the city. Often social infrastructure is seen around these urban green areas.

London has nearly half of its area coverage constituting open green spaces letting 31.69 sq. m green space per person (16.13 sq. m referred to parks) (Usborne 2014). Greenspaces are often used in a marked way to carry controlled beneficial interventions for vulnerable groups such as youngsters at risk, persons living with depression, dementia or ill-health, probationers and stressed workers. Interventions include creating pedestrian accessibility and finding walkable areas in open, green spaces. For example, for adolescents with behavioural or self-esteem issues, greenspaces are used as channels for reflection over week-long expeditions, with relevant psychological and behavioural improvements frequently reported, such as enhanced self-esteem, self-efficacy, image, empowerment, control, self-confidence, and decision making. For individuals living with dementia, interacting with greenspaces can definitely influence eating and sleeping rhythms, fitness and mobility, sense of comfort, self-confidence and regulation related to enhanced social communication and a sense of fitting in.

This enhances the relevance of a study that can identify the variables that influence development and usage of open and green spaces contributing to good health. Living in areas that offer mixed usage and easy connectivity, availability and free access to all can allow healthy networks. This study thereby can be used to understand by certain areas within the same region have varying health levels.

1.2 CASE STUDY

Camden, a central London borough, has one of the largest health disparity gaps in England and people suffering from poor health are generally focussed in some of the borough's most deprived wards. (There are wards falling under 10% most deprived-source: Indices of Deprivation 2019, MHCLG) Addressing these variations and improving Camden's wellbeing goes beyond improving access to medical facilities

and this includes a range of measures to improve our social and physical environment through green spaces. Camden's Local Plan 2017 mentions there is 4.3 sqm green space per capita, and 65.7% of Camden homes have a deficiency in to access to a local, small or pocket park. Additionally, it is notable that there are multiple indices of deprivation that might be linked to factors like housing, income, education, employment and so on affecting a healthy lifestyle that could be explored.

1.3 TYPOLOGY OF SPACE CONSIDERED FOR STUDY

For the purpose of this research, the areas taken into account are derived from the specifications provided (Table 1 and 2) by Atkins 'Camden Open Space, Sport and Recreation Study' below. These spaces are then mapped into GIS and used accordingly.

Table 1: The specifications and descriptions of the spaces considered for the purpose of the study (Atkins 2014).

Type of Open Space	Definition
Parks and Gardens	Includes urban parks, country parks and formal gardens. These are defined as accessible spaces, offering high quality opportunities for informal recreation and community events.
Amenity Green Space	Includes informal recreational spaces and housing green spaces. This category would include green spaces in and around housing areas, large landscaped areas, and domestic gardens as well as informal 'kick-about' play areas for children.
Outdoor Sports Facilities / Playing Fields	Those sites which are not located within a public park and which the primary role is for formal recreation. Sites include tennis courts, bowling greens, sports pitches, golf courses, athletics tracks, school playing fields, other institutional playing fields and outdoor sports areas. Categorise by ownership i.e. public/private/education.
Allotments / Community Gardens / Urban Farms	Open spaces where the primary use is allotment gardening or community farming.
Cemeteries and	Open space where primary use is burial.

Table 2: The specifications and descriptions of the spaces considered for the purpose of the study (Atkins 2014).

Open Space Categorisation	Approx Size of Open Space and Distance from Home	Characteristics
Regional Parks and Open Spaces	400 hectares	Large areas and corridors of natural heathland, downland, commons, woodland and parkland also including areas not publically accessible but which contribute to the overall environmental amenity.
(Linked Metropolitan Open Land and Green Belt Corridors)	3.2 - 8km	
Weekend and occasional visits by car or public transport		Primarily providing for informal recreation with some non-intrusive active recreation uses, car parking at key locations.
Metropolitan Parks	60 hectares	Either natural heathland, downland, commons, woodlands etc, or ii) formal parks providing for both active and passive recreation.
Weekend and occasional visits by car or public transport	3.2km or more where the park is appreciably larger.	May contain playing fields, but at least 40 hectares for other pursuits. Adequate car parking.
District Park	20 hectares	Landscape setting with a variety of natural features providing for a wide range of activities, including outdoor sports facilities and playing fields, children's play for different age groups, and informal recreation pursuits. Should provide some car parking.
Weekend and occasional visits by foot, cycle, car and short bus trips	1.2 km	
Local Parks	2 hectares	Providing for court games, children's play spaces or other areas of a specialist nature, including nature and conservation areas.
Pedestrian Visits	0.4km	
Small Local Parks and Open Spaces	0.4 - 2 hectares	Gardens, sitting-out areas, children's play spaces or other areas of a specialised nature,
Pedestrian visits especially by children, particularly valuable in high density areas.	Less than 0.4km	including nature and conservation areas.
Pocket Parks	Under 0.4 hectares	Gardens, sitting-out areas, children's play spaces or other areas of a specialised nature, including nature and conservation areas.
Pedestrian visits especially by children.	Less than 0.4km	

Camden is a central, green area in London, and London is a privileged city compared to many cities in the word. (Ranking 37 in cost of living- Cost of Living Index 2021). Exploring health impacts on surrounding neighbourhoods, this research focuses on the measurable differences in access to green space within the different neighbourhoods in Camden that are subject to various socio-economic key features that result healthy wellbeing to answer the question. Using the spatial variables that impact health, how the spatial configuration affects areas of high health deprivation has been explored. Camden Local Plan outlines the intention of the creation of by improving services and infrastructure. Space Syntax Analysis offers the potential to study the impact of health values in regions of high social housing-residential density through metric step depth and catchment analysis, to and from parks. Thus, do people living in low deprivation areas have greater access to parks, streets with good walkability than those in low deprivation?

2 THEORY

Walking is said to influence health. Good walkable areas can create active neighbourhoods (Geddes & Vaughan, 2014). There are studies that showcase perceived safety of green spaces and active neighbourhoods with improved accessibility to stores, transits and recreational areas. They reveal greater use of green spaces in spatial networks through integration and inter-visibility which show improved levels of walking and therefore health. In their research, they suggest that the degree of familiarity, also shapes the extent and patterns of walking and with multiple user groups. There are also different impacts on use of built environments in a neighbourhood on levels of walking for purposes that are not for exercise (Geddes & Vaughan, 2014). The results show an interlink between the urban morphology, land use location and routes taken by the user in the three cases Barnet, Surbiton and Norwood.

Street-level greenery can impact walkability, for example-people choose routes that are greener. Evidence from Hong Kong predicts that They predict that 70% of the global population would be living in urban areas by 2050. This rapid urbanisation can continue to deplete green coverage which might have negative effects on residents' health and well-being (Yi et al. 2018). With the hypothesis that walking and physical activity are mediators for urban green and health levels, most research focuses on parks rather than green and landscaped streets. These street level studies indicate that walking behaviours control sociodemographic characteristics considering activities in the built-environment cluster. The results summarise that greenery and higher park areas were in tandem to higher walking levels (but not associated with total walking time). The walking behaviour and health would thus, seem heavily influenced with visibility of strong eye-level street greener as by parks (Yi et al. 2018).

There are positive effects of green urban spaces on individual behaviour, health and activity. (Sarkar et al. 2015). The street level accessibility model reports a connection between walking and density of trees aligned on the streets, showing beneficial measures of distance through usage of green spaces or areas with street trees. This explores associations between urban green, street Design and walking. The research shows results from Greater London boroughs that have green spaces influencing active travel (walking and cycling) physical activity and therefore health and mortality levels, which is studied against vehicular movement needs to encourage creation of shared spaces. The conclusions discuss that urban health can be nurtured through optimised morphology – shape, size and intensity of green in terms of social dynamics in micro-neighbourhoods influencing individuals to walk more (Sarkar et al. 2015).

Studies on Green space, urbanity and health display Recent decline in green spaces in European cities. It explores how these spaces in 1-3km radius or local neighbourhoods can have positive impacts specifically in urban areas (Maas et al. 2006). This was shown through high negative correlations between amount of green area and degree of urbanity. Quantity of economic considerations prevailing in spatial planning that do not give importance to green spaces, which ultimately can have change in health and development particularly with elderly, children and secondary-educated socio-economic groups that showed a larger co-relation to the presence of green spaces. Green area is impacts perceived general health than the degree of urbanity itself suggesting that it may have an independent effect on health regardless of the degree of

urbanity; however, usage of any green space in urban areas still exhibit improved health levels in cities (Maas et al. 2006).

The theory of cities as 'movement economies' (Hillier, 1996a, 1996b) derives from 'natural movement' (Hillier, Penn et al. 1993) that affects land use distribution across the city which helps look at the angular and metric attributes factoring the angular change corresponding with closeness-centrality and betweenness-centrality known as integration and choice respectively (Freeman et al., 1977, Hillier and Iida 2005). The integration, shows the sum of the shortest path between origin and destination. The higher its value, it is likely to become 'to-movement '. Choice shows the path overlap between origin and destination; higher the value, more likely is used as a through-movement path. These ideas are derived from graph theory describing the to and through movement potentials, i.e., configuration of streets and public spaces by users and how they transit within the streets of the city. In order to compare cities, the values used are normalised angular integration (NAIN) and normalised angular choice (NACH) which show closer correlation to actual movements (Hillier et al. 2012) and also to compare different locations within the same city (Al-Sayed et al., 2014, p. 77).

Physical attributes of a neighbourhood can affect the social "behaviour" of its residents (Third places as valued local social places where residents who spent most of their day at home because they were unemployed, in poor health, retired or had childcare responsibilities, made greater use of them. And therefore, as a result, not surprisingly, more of their social interactions occurred in these places (Sennett, 1992; Goodchild, 2008). The regions that are not centres have lower local and global choice at increasing radii values until they are consistent at global choice. This knowhow can help decode the reasons for health level reports in different areas by understanding the position of activities and social infrastructure within the community.

3 DATASETS AND METHODS

3.1 STUDY AREA

For the purpose of this study, two areas within Camden were selected (Figure 1)-
Study area 1 is larger in area, bordered by metropolitan parks and Study area 2, has only pocket parks. This is selected in order to exhibit the differences between them in terms of availability and access. What are the differences in Study areas 1 and 2 and the ratio of open -green spaces? Access to social infrastructure plays a role in reported health levels of a space for example there are usable gyms, recreational spaces, shops and activities for leisure apart from green spaces, that impact individual and collective health, therefore the question: Is there a measurable difference in health levels in areas 1 and 2 with the understanding that regions in study area 2 have more social infrastructure available?

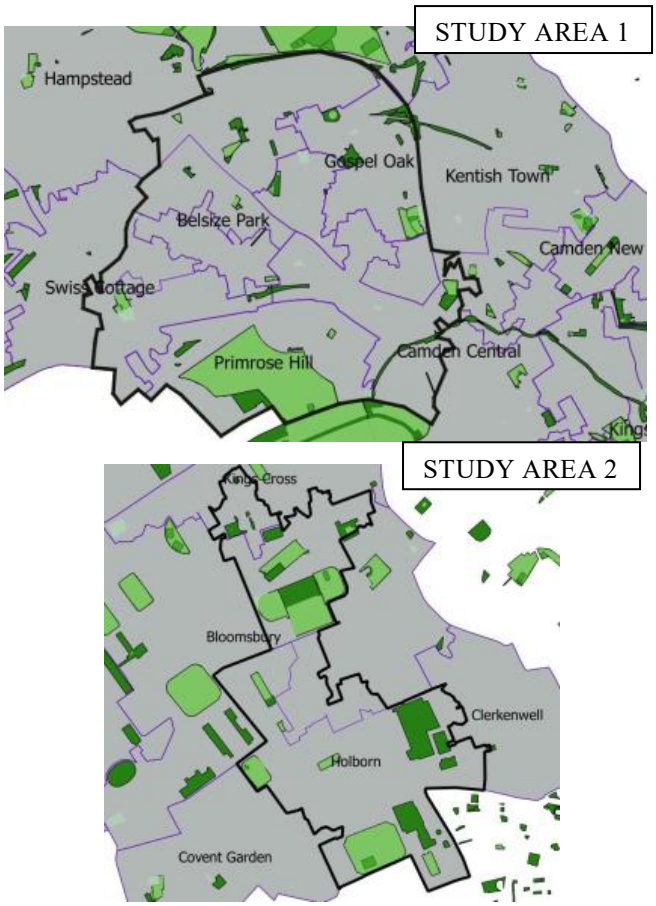


Figure 1: The boundaries of study area 1 and 2 chosen for the study.

The research follows a basic outline of using Census data within these areas that are mapped on to GIS software. Socio-economic data and Indices of deprivation (section 3.3) is collected at the level of Lower Layer Super Output Areas (LSOAs) for both before Area 1 and 2. Parallelly, spatial models for these areas are prepared. The model involves multi-variable space syntax analysis. It identifies variables that need to be joined together and mapped on to space through spatial joins. The availability of open areas and green areas are measured against social infrastructure and social housing as a separate exercise.

The change in socio-economic parameters are identified and their relationship to spatial changes are tested as well as the relationship of these changes to the health values itself is tested. This is done through angular segment analysis, metric step depth (from parks and social housing units) and catchment analysis of the areas around parks and social housing. Finally, the differences are noted and statistically tested, which is analysed with correlations and regression models.

3.2 SCOPE OF STUDY

The spatial accessibility and socio-economic parameters that are relevant to the impact study have been chosen by the counts for social infrastructure, residential density of social housing and no. of green and open spaces available in the selected area. This are selected since they seem to be important to compare the access and availability between areas of high and low health deprivation that can be traced back to areas of high or low residential density social housing units. Since the health levels also suggest a significant connect to the third places, social infrastructure count of the region has been taken into account.

3.3 INDICES OF MULTIPLE DEPRIVATION

The Index of Multiple Deprivation ranks every small area in England from 1 (most deprived area) to 32,844 (least deprived area), (Calculating IMD: Office for National Statistics). It is common to describe how relatively deprived a small area is by saying whether it falls among the most deprived 10 per cent, 20 per cent or 30 per cent of small areas in deciles in England (although there is no definitive cut-off at which an area is described as 'deprived'). To help with this, deprivation 'deciles' are published alongside ranks. Deciles are calculated by ranking the 32,844 small areas in England from most deprived to least deprived and dividing them into 10 equal groups. These range from the most deprived 10 per cent of small areas nationally to the least deprived 10 per cent of small areas nationally.

3.4 MAPPING HEALTH

A question on self-assessed general health was included in both the 2001 and 2011 Censuses was as follows "In 2001, each person in a household was asked to rate their general health over the last 12 months; the possible responses were 'Good', 'Fairly good' or 'Not good'. In 2011 each person in the household was asked to rate their health in general; the possible responses were 'Very good', 'Good', 'Fair', 'Bad' and 'Very bad'. Unlike simple indicators based on the presence or absence of disease, an important property of the general health status indicator is that it includes the entire spectrum of health states ranging from 'Good' to 'Not good' health." -Office for National statistics Overall, 81.2% of people reported their general health as either "very good" or "good in London.

3.5 Angular segment analysis

An angular segment analysis was performed, the maps were stylised in QGIS. The spatial data was summarised to derive values of NAIN and NACH at selected radii for the study areas 1 and 2 which are helpful to compare. The distance measured is calculated through angular change due to movement from one segment to another, which reflects people's actual movement patterns from space to space rather than intersections (Dhanani et al., 2017:60).

NACH = logCH+1/logTD+3
NAIN = NC^1.2/TD

3.6 Step depth and Catchment Analysis

Step depth shows the shortest angular path from a selected segment to all other segments within the system. The study aims to use the local centres identified as the selected segment to calculate step depth to all the segments in the system. A buffer zone is created depending on the intensity of the adjacent land use which helps define the buffer size through distance. The data is then merged with the segment, using a spatial join. This would help recognise the proximity to the local activities with the area. The road network showcases the continuous spatial structure and doesn't fully accommodate the movement pauses as nodes

and streets as edges. The catchment analysis enables the examination of usage in a contained boundary to evaluate the walking accessibility by the inhabitants of the chosen areas.

A fixed distance buffer of 10m was created around the geolocated point co-ordinates of parks or railway station or social infrastructure. This was then joined to the segment map (where the health data has already been mapped on) using a spatial join. A step depth analysis was run from the variable mentioned in the study, and the highest values were obtained on all the segments adjacent to the central street segment of the borough where the spatial join was conducted by joining attributes by location. The geometry predicates included point co-ordinates that 'intersects', 'contains', 'equals', 'overlaps', 'touches', 'within' and 'crosses' the segment map. The attribute summary was taken for intersecting features before running the step depth or catchment analysis.

3.7 Availability ratio

The datasets for health deprivation of each ward, social housing and social infrastructure in the region were mapped along with green and open spaces to compare the data for highly deprived LSOAs and lesser deprived LSOAs. Each LSOA was given a number chronologically.
The availability ratios for the following were looked at:

- Social housing (Residential density): Open spaces
- Social housing (Residential density): Green spaces
- Green spaces: open space
- Social housing: Social infrastructure

3.8 LIMITATIONS

Only about 70% participate and report health levels in the Census. A wholistic parameter to understand the levels of health is not proposed as a question or particular health levels and the reasons for variation is not considered. For this study, only general health is considered and other factors like variable mental illnesses, provision of unpaid health care and long-term disability and for how many hours or sickness and how much movement is restricted because of the same is not considered.

4 RESULTS

4.1 SPATIAL ACCESIBILITY- ANGULAR SEGMENT ANAYLSIS

The values of NACH (Figure 2) and NAIN (Figure 3) were taken for R400, R800, R1000, R2000, R3000 and R5000 to show variations in the local and global scale. These are normalised measures so that they could be compared on various scales in different cities of different sizes.

4.2 NORMALISED ANGULAR CHOICE

Study area 1: Normalised Choice value is higher on the high streets (Source-OSM) running across Camden and its perimeter at the NACH R800, NACH R 1000 and NACH R 2000. There is high choice value at the

main streets (value = 1.29-1.54) and neighbourhood borders. But at NACH R400 the value falls at the inner secondary (0.98-1.08) and tertiary street level
(0.72-0.84)

Study area 2: NACH R400, NACH R800 indicated that the main roads cutting within the neighbourhoods have higher values and the inner tertiary routes have least choice seen in blue. (0-0.89) NACH R3000 and NACH R5000 shows high choice values of streets cutting through the centre of the neighbourhoods within the study area. (1.10-1.46) Circled values indicate range of the region.

4.3 NORMALISED ANGULAR INTEGRATION

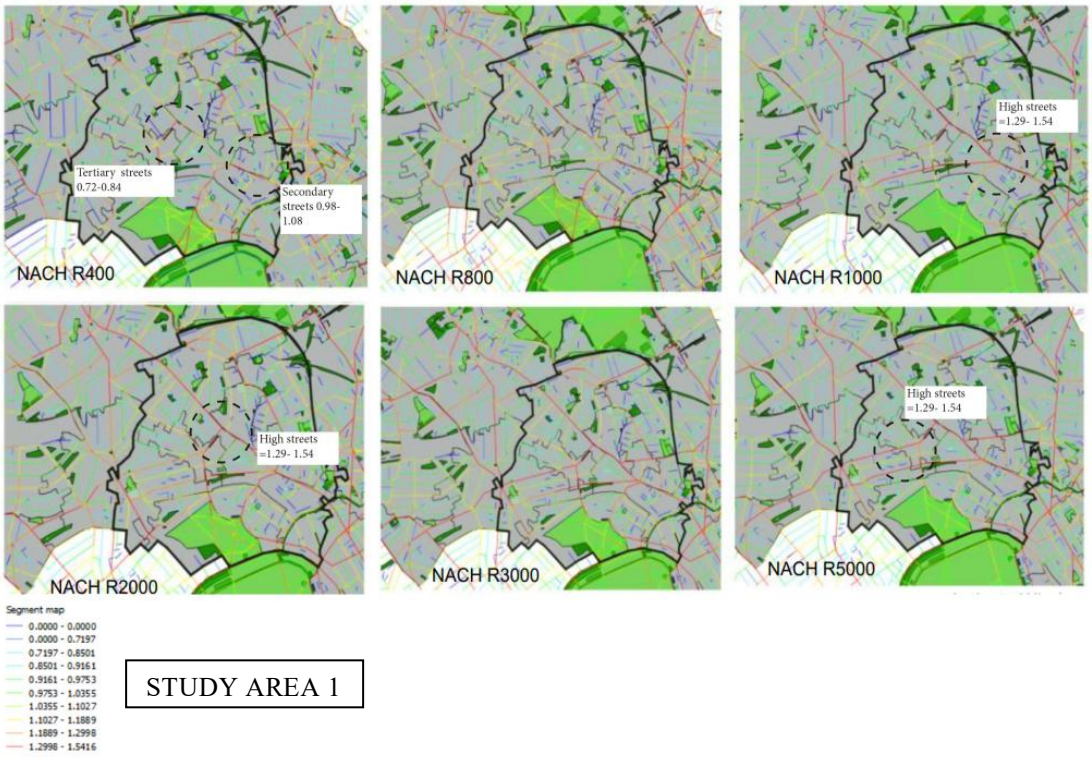
Study area 1: NAIN R400, NAIN R800 indicated that the main roads of the neighbourhood boundaries are highly integrated and the inner routes are much less integrated. (The value drops from 1.54 to 0.91) Near the neighbourhood boundaries at R1000 and R2000 the values are higher (between 1.32-1.51)
NAIN R3000 and NAIN R5000 shows a highly integrated street network in most neighbourhoods (slightly lower, 0.72-0.85 within the regions of a large park towards North of Camden).
Circled values indicate range of the region.

Study area 2: NAIN R400, NAIN R800 have very few streets with high integration (0.24-1.1) but in NAIN R1000, most streets are highly integrated within each LSOA. The values fall for tertiary street connections. NAIN R3000 and NAIN R5000 shows highly integrated primary and secondary streets.
Circled values indicate range of the region.

4.4 CATCHMENT ANALYSIS

A catchment analysis was done to further understand the relationship of health deprivation levels and parks to social infrastructure and value of NACH to understand the variation in values (Figure 4).

Study area 1A: A spatial join was used to join the health deprivationdata to the segment map and map it against ChoiceR1200, the centres of each LSOA has high choice(2-350) value, indicating the internal areas are well used. The areas near the metropolitan open and green spaces have lower choice value. (600-980
Study area 1B: A spatial join was used to join the park access points on the segment map and understand access to social infrastructure around them within a ten-minute walk.
This region has social infrastructure or third places centrally as opposed to near the boundary of the metropolitan park within each ward indicated by high values (82-194)



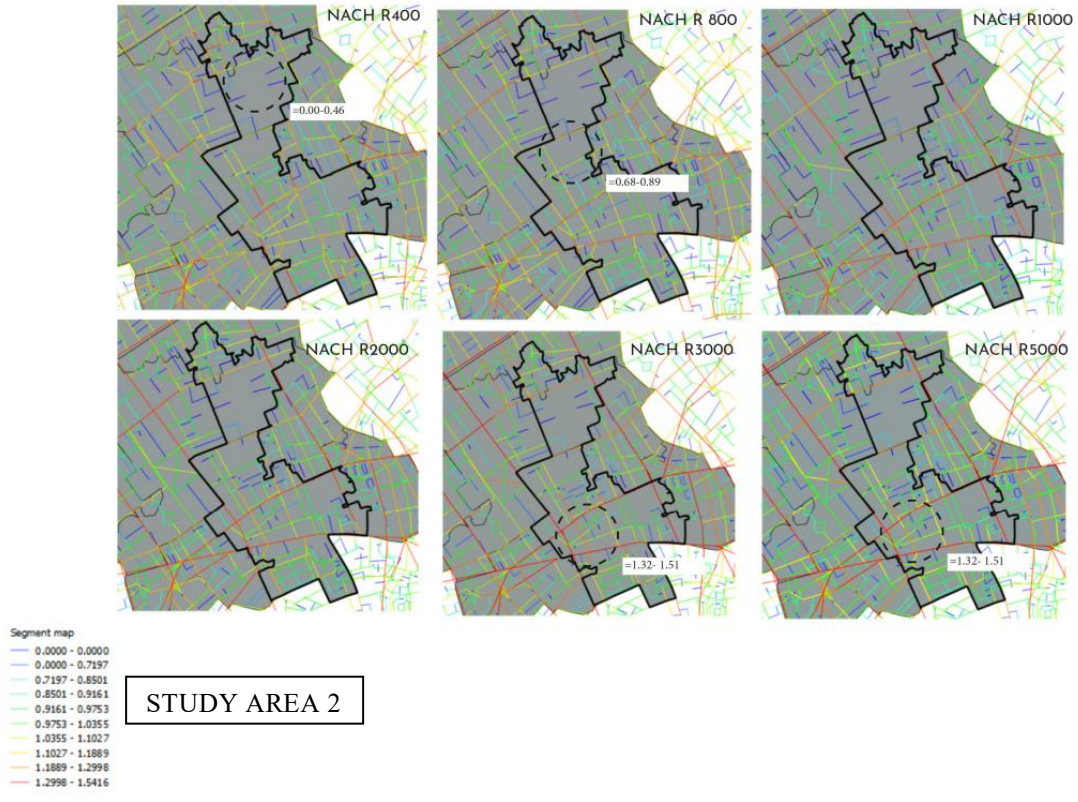


Figure 2: The values for NACH R 400 to NACH R5000 for Study area 1 and 2

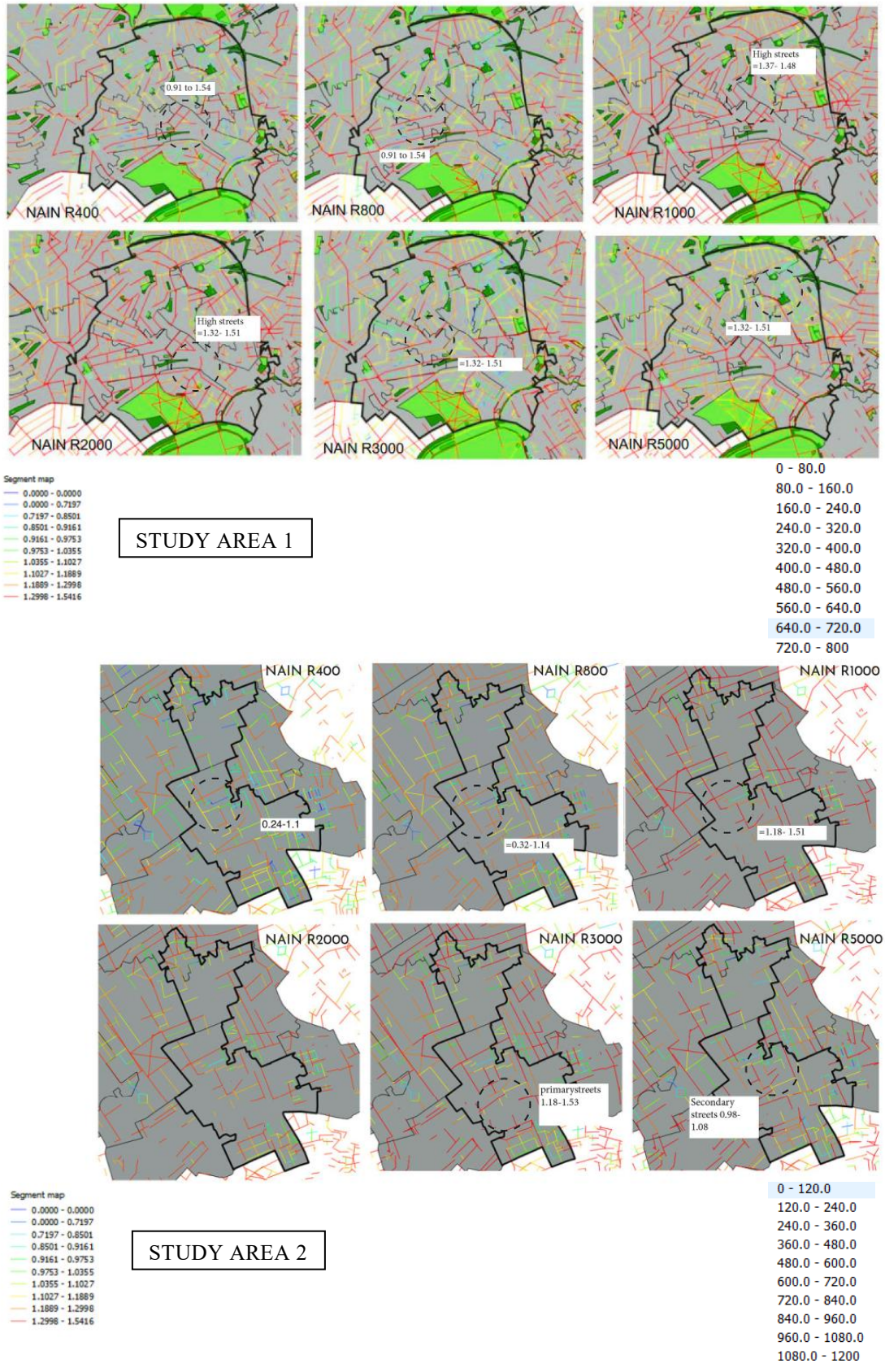


Figure 3: The values for NAIN R 400 to NAIN R5000 for Study area 1 and 2

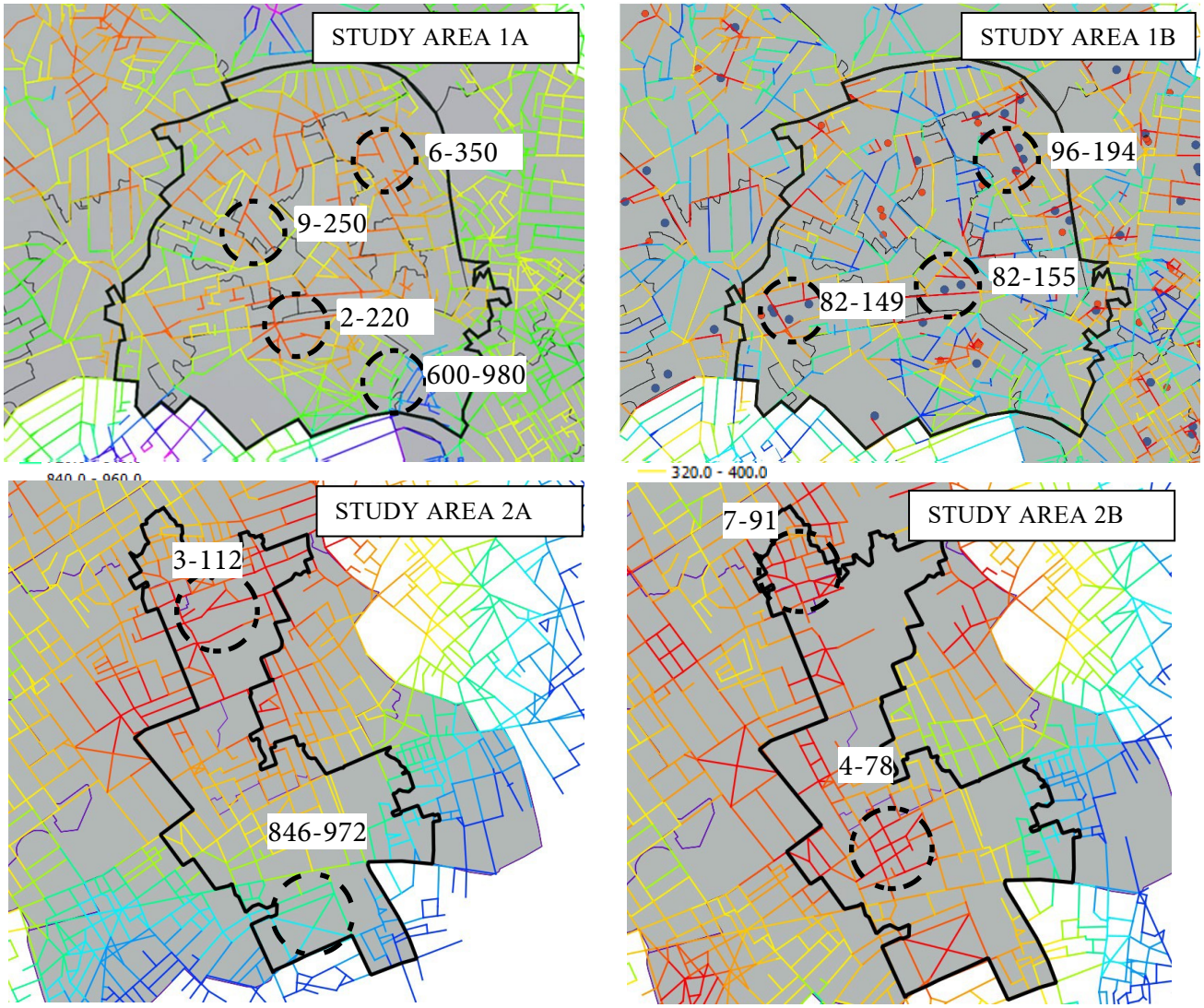


Figure 4: Catchment analysis for the following:
Study area 1A- Health deprivation and Choice R1200
Study area 1B- Parks to Social Infrastructure R800
Study area 2A- Health deprivation and Choice R1200
Study area 2B- Parks to Social Infrastructure R800

Study area 2A: A spatial join between Health deprivation levels and Choice R1200 was made, it is seen that less deprived areas lying on the northern region of the study area has higher choice values (3-112) compared to the south that has higher health deprivation rates and lower choice (846-972)
Study area 2B: A spatial join was made between the access points of the parks in the study area on the segment map and then put against social infrastructure (4-91) available in the region, All the wards have high access to social infrastructure towards the western ends of the study area from the parks.

4.5 4.1.4 STEP DEPTH ANALYSIS

A metric step depth was conducted to the railway stations in study areas 1 and 2 to compare access to transport within a ward unit that surrounding green and open spaces (Figure 5).

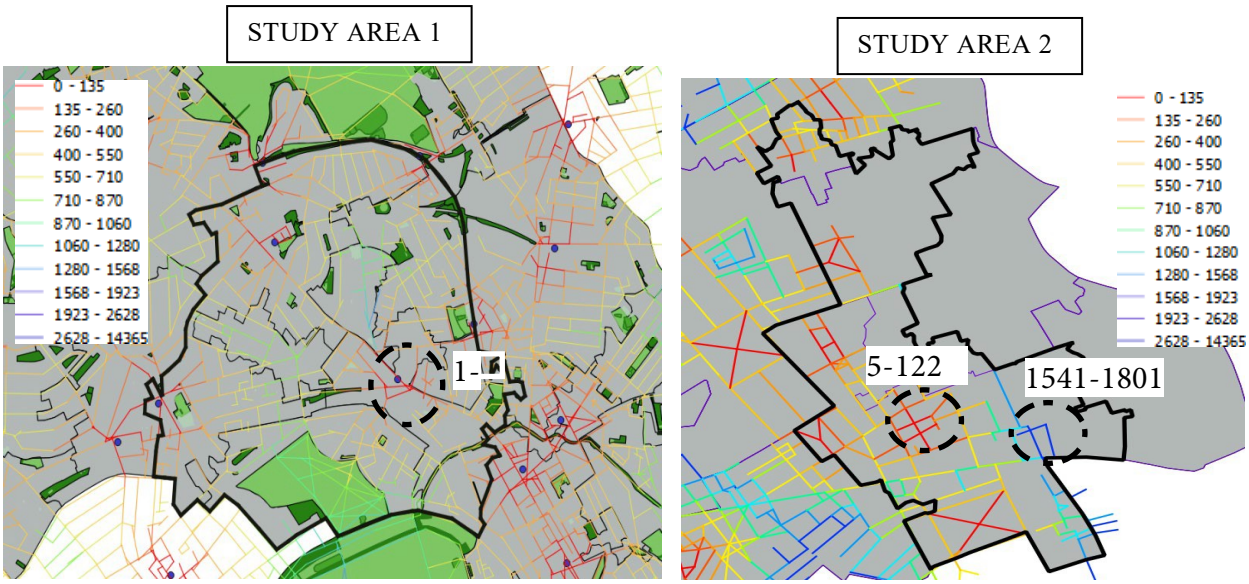


Figure 5: Metric Step depth- Railway Stations for study areas 1 and 2

Study area 1: The railway stations lie along the high streets or very close to major road junctions. The centre of the study area also has a few stations making the access to railway both in the centre and periphery.

Study area 2: The study area has access to railway stations on the western end, The values are higher (5-122) around the railway station, but falls out its periphery, the main roads connecting to high streets have low values. (1541-1801)

4.6 AVAILABILITY RATIO

Study area 1 and 2 were divided into their LSOA units and the values reported for Health deprivation were plotted using the values published by the Census data. The legend for the same is given below. This was the first step to then on compare the count of social infrastructure, residential density of social housing units against green and open spaces (Figure 6) .

4.7 SOCIAL HOUSING: OPEN SPACES

The values for each region having Health deprivation data were explored and the residential density was calculated by understanding the number of tenant properties available in social housing areas. Then, the area for each open space was calculated separately and written against the appropriate location. Finally, a ratio was calculated between Residential density of social housing and open spaces in the region (Table 2).

It is seen that there are no open spaces in some regions (highlighted), this is because some regions do not contain open spaces and some categorise parks as only green spaces.

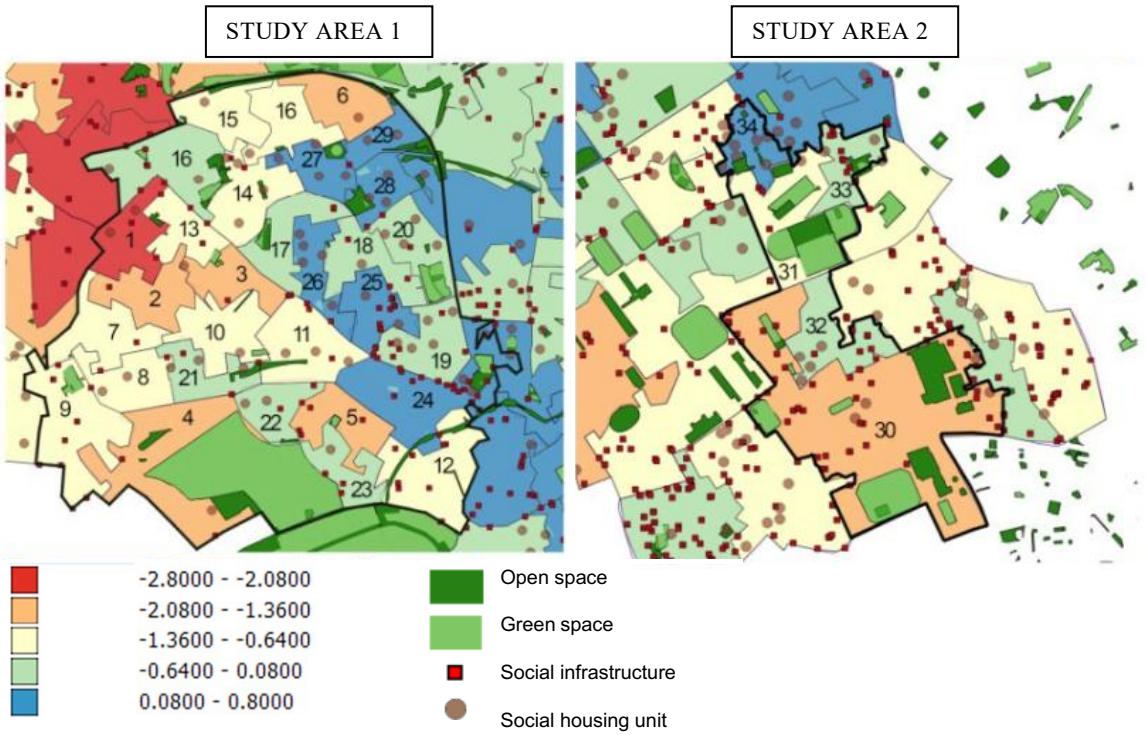


Figure 6: Indication the region division for the purpose of ratio calculation in study area 1 and 2

Region 4 and 23 has one of the highest availabilities of green space area, since it contains a Metropolitan park- Primrose Hill.

REGION	COLOUR	RESIDENTIAL DENSITY	OPEN SPACE TOTAL	RATIO
1	RED	3.1	969.48	0.319759046
2	ORANGE	0	0	0
3	ORANGE	5.1	2189.3707	0.232943649
4	ORANGE	4.7	152426.94	0.003083444
6	ORANGE	3.9		0
7	YELLOW	0	94.8	0
8	YELLOW	25.4	0	0
9	YELLOW	0	8313.72	0
10	YELLOW	4.3	2546.81	0.168838665
11	YELLOW	9.4	1811.86	0.518803881
12	YELLOW	0	7805.67	0
13	YELLOW	0	1269.76	0
14	YELLOW	9.4	2305.62	0.407699447
15	YELLOW	9.4	6551.52	0.143478155
16	GREEN	17.6	13847.55	0.127098295
17	GREEN	0	6517.94	0
18	GREEN	19.2	250.06	7.678157242
19	GREEN	38.6	0	0
20	GREEN	27.8	19573.45	0.142029126
21	GREEN	33.3	4629.33	0.719326555
22	GREEN	12.4	953.85	1.299994758
23	GREEN	1.8	122868.17	0.001464985
24	BLUE	4.8	12954.06	0.03705402
25	BLUE	47.5	0	0
26	BLUE	31.6	0	0
27	BLUE	58.3	5938.82	0.981676495
28	BLUE	43.1	9815.08	0.439120211
29	BLUE	28.1	13232.49	0.212356102
30	ORANGE	9	51686.34	0.017412725
31	YELLOW	10.2	31899.93	0.031974992
32	GREEN	26.6	0	0
33	GREEN	16.3	4432.56	0.367733319
34	BLUE	21	3525.76	0.595616264

Table 2: All regions in Study area 1 and 2 showing the area of open space they contain

4.8 SOCIAL HOUSING: GREEN SPACES

A ratio was calculated between Residential density of social housing and green spaces in the region.

It is seen that there are no green spaces in some regions, (highlighted) this is because some regions do not contain open spaces and some categorise parks as only green spaces.

Region 4 and has one of the highest availabilities (under green space total in Table 3) of green space area, since it contains a Metropolitan park- Primrose Hill.

REGION	COLOUR	RESIDENTIAL DENSITY	GREEN SPACE TOTAL	RATIO
1	RED	3.1	0	0
2	ORANGE	0	1130.11	0
3	ORANGE	5.1	2268.87	0.224781499
4	ORANGE	4.7	129859.81	0.003619288
5	ORANGE	0	0	0
6	ORANGE	3.9	0	0
7	YELLOW	0	0	0
8	YELLOW	25.4	165.07	15.3874114
9	YELLOW	0	15991.31	0
10	YELLOW	4.3	1698.26	0.253200334
11	YELLOW	9.4	0	0
12	YELLOW	0	557.07	0
13	YELLOW	0	1130.03	0
14	YELLOW	9.4	0	0
15	YELLOW	9.4	464.75	2.022592792
16	GREEN	17.6	5349.72	0.328989181
17	GREEN	0	8180.54	0
18	GREEN	19.2	271.48	7.072344187
19	GREEN	38.6	501.53	7.696448866
20	GREEN	27.8	3582.36	0.776024743
21	GREEN	33.3	579.79	5.743458839
22	GREEN	12.4	303.5	4.085667216
23	GREEN	1.8	127079.42	0.001416437
24	BLUE	4.8	7998.05	0.060014629
25	BLUE	47.5	218.45	21.7441062
26	BLUE	31.6	1896.18	1.666508454
27	BLUE	58.3	2436.6	2.392678322
28	BLUE	43.1	2903.76	1.484282448
29	BLUE	28.1	2319.16	1.211645596
30	ORANGE	9	43481.95	0.020698244
31	YELLOW	10.2	25203.23	0.040471003
32	GREEN	26.6	0	0
33	GREEN	16.3	1079.69	1.509692597
34	BLUE	21	69.01	30.43037241

Table 3: All regions in Study area 1 and 2 showing the area of green space they contain

4.9 OPEN SPACE: GREEN SPACE

Using Ratios 1 and 2 which is residential density of social housing by openspaces and green spaces respectively, the common factor of residential density was removed to present a value of open spaces by greenspaces (Table 4). The value of this ratio is directly proportional to the available openand green space area.

If the ratio is 0, it is because there is no open space or green space or within the region (highlighted).

REGION.	COLOUR	OPEN SPACE TOTAL	GREEN SPACE TOTAL	RATIO
1	RED	969.48	0	0
2	ORANGE	0	1130.11	0
3	ORANGE	2189.3707	2268.87	0.96496084
4	ORANGE	152426.94	129859.81	1.17378071
5	ORANGE	0	0	0
6	ORANGE	0	0	0
7	YELLOW	94.8	0	0
8	YELLOW	0	165.07	0
9	YELLOW	8313.72	15991.31	0.519889865
10	YELLOW	2546.81	1698.26	1.499658474
11	YELLOW	1811.86	0	0
12	YELLOW	7805.67	557.07	14.01200926
13	YELLOW	1269.76	1130.03	1.123651584
14	YELLOW	2305.62	0	0
15	YELLOW	6551.52	464.75	14.09686928
16	GREEN	13847.55	5349.72	2.588462574
17	GREEN	6517.94	8180.54	0.796761583
18	GREEN	250.06	271.48	0.92109916
19	GREEN	0	501.53	0
20	GREEN	19573.45	3582.36	5.463842272
21	GREEN	4629.33	579.79	7.984494386
22	GREEN	953.85	303.5	3.142833608
23	GREEN	122868.17	127079.42	0.966861275
24	BLUE	12954.06	7998.05	1.61965229
25	BLUE	0	218.45	0
26	BLUE	0	1896.18	0
27	BLUE	5938.82	2436.6	2.437338915
28	BLUE	9815.08	2903.76	3.380127834
29	BLUE	13232.49	2319.16	5.705725349
30	ORANGE	51686.34	43481.95	1.18868496
31	YELLOW	31899.93	25203.23	1.265708006
32	GREEN	0	0	0
33	GREEN	4432.56	1079.69	4.105400624
34	BLUE	3525.76	69.01	51.09056658

Table 4: All regions in Study area 1 and 2 showing the area of open by green space they contain

Using Ratios 1 and 2 which is residential density of social housing by open spaces and green spaces respectively, the common factor of residential density was removed to present a value of open spaces by green spaces. The value of this ratio is directly proportional to the available open and green space area.

If the ratio is 0, it is because there is no open space or green space or both in the region (highlighted).

4.10 SOCIAL HOUSING: SOCIAL INFRASTRUCTURE

The third places or social infrastructure, a whole number value is considered through mapping the most prominent social infrastructure in each region. Then the valueof social housing-residential density and the whole number value for social infrastructure are divided to get the ratio (Table 5).

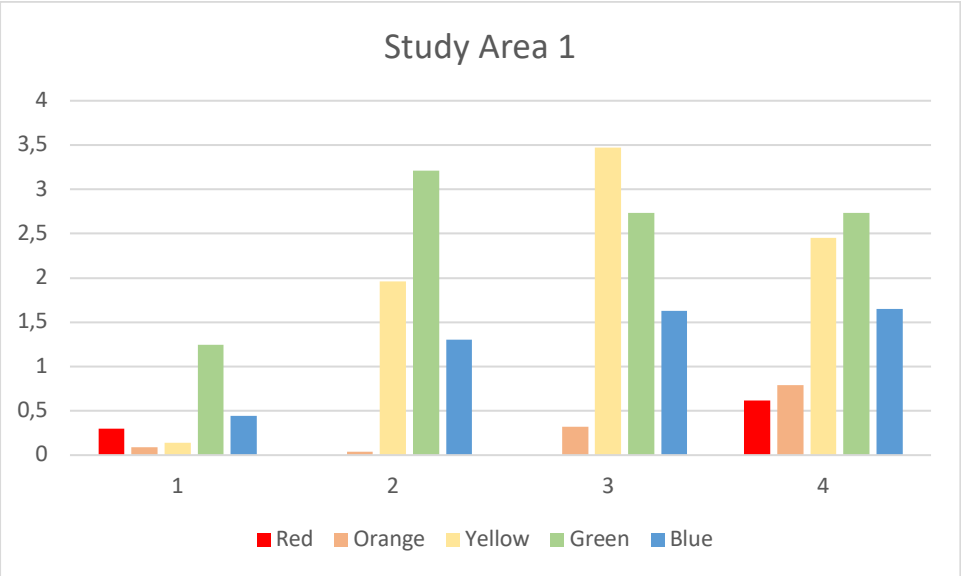
Some areas have 0 ratio because they either contain no socialhousing unit or social infrastructure (highlighted).

REGION	COLOUR	RESIDENTIAL DENSITY	SOCIAL INFRASTRUCTURE	RATIO
1	RED	3.1	5	0.62
2	ORANGE	0	1	0
3	ORANGE	5.1	2	2.55
4	ORANGE	4.7	3	1.566666667
5	ORANGE	0	4	0
6	ORANGE	3.9	0	0
7	YELLOW	0	2	0
8	YELLOW	25.4	2	12.7
9	YELLOW	0	8	0
10	YELLOW	4.3	0	0
11	YELLOW	9.4	2	4.7
12	YELLOW	0	10	0
13	YELLOW	0	5	0
14	YELLOW	9.4	2	4.7
15	YELLOW	9.4	0	0
16	GREEN	17.6	4	4.4
17	GREEN	0	2	0
18	GREEN	19.2	3	6.4
19	GREEN	38.6	13	2.969230769
20	GREEN	27.8	2	13.9
21	GREEN	33.3	3	11.1
22	GREEN	12.4	3	4.133333333
23	GREEN	1.8	5	0.36
24	BLUE	4.8	17	0.282352941
25	BLUE	47.5	10	4.75
26	BLUE	31.6	1	31.6
27	BLUE	58.3	1	58.3
28	BLUE	43.1	1	43.1
29	BLUE	28.1	2	14.05
30	ORANGE	9	45	0.2
31	YELLOW	10.2	2	5.1
32	GREEN	26.6	9	2.955555556
33	GREEN	16.3	13	1.253846154
34	BLUE	21	4	5.25

Table 5: All regions in Study area 1 and 2 showing the area the amount of social infrastructure they contain

4.11 COMPARISION GRAPH

- Ratio 1: Social housing (Residential density): Open spaces
- Ratio 2: Social housing (Residential density): Green spaces
- Ratio 3: Green spaces: open space
- Ratio 4: Social housing: Social infrastructure



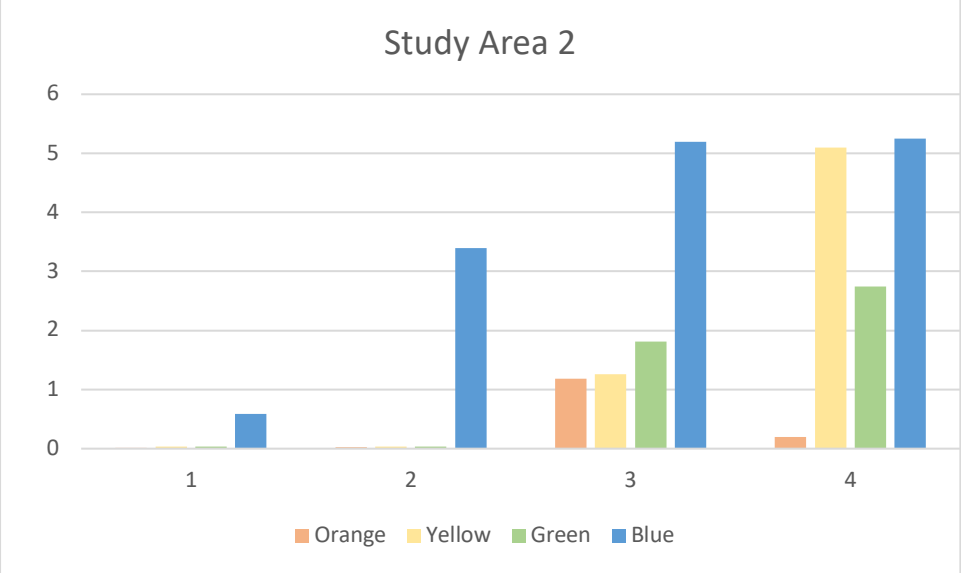


Figure 7: Bar graphs indication the average ratios of availability of open, green and social infrastructure in study area

STUDY AREA 1

X axis	Ratio 1	Ratio 2	Ratio 3	Ratio 4
Red	0.3	0	0	0.62
Orange	0.088833	0.037167	0.32	0.789333
Yellow	0.137647	1.962578	3.472453	2.455556
Green	1.246009	3.213044	2.733044	2.733044
Blue	0.443122	1.303197	1.631374	1.649483

STUDY AREA 2

X axis	Ratio 1	Ratio 2	Ratio 3	Ratio 4
Orange	0.017	0.02	1.18	0.2
Yellow	0.03	0.04	1.26	5.1
Green	0.032	0.04	1.81	2.75
Blue	0.59	3.4	5.19	5.25

Table 6 The average values for Study area 1 and 2 were calculated and plotted as a table

The most deprived region (highlighted in Study area 1 in Figure 7) lacks open and green spaces. The average value for each ratio was calculated based on the health deprivation colour for the region, it shows the availability of open, and green spaces and social infrastructure put side by side.

Study Area 1 shows a higher overall ratio of open-green spaces because it is a larger area. However social infrastructure value is higher in Study area 2 even though there are fewer parks and it is not close to any large metropolitan area.

4.12 PLOTTING REGRESSION LINE

The precise value of health deprivation is noted for regions 1 to 34 divided in study area 1 and 2 (for availability ratio) and other variables like connectivity, segment length and finally multiple radii of Normalised Angular choice and Normalised integration with Health deprivation values as the dependent variable (Table 7). This is done to see the type of correlation, if any and the value obtained between the two variables. The values for variables of residential was chosen since they had higher correlation values. (Further away from 0 than other variables.) This shows us there may be a linear correlation between the independent variable-residential density and dependent variable-health deprivation values (Figure 8).

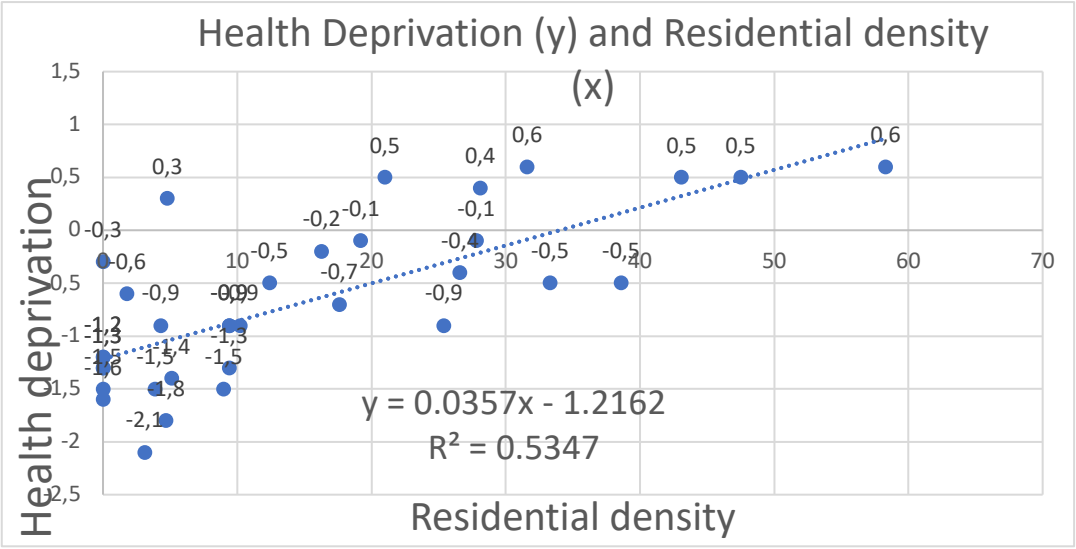


Figure 8: Scatter plots of Health deprivation vs. independent variable Residential density

RESIDENTIAL DENSITY	ANGULAR CONNECTIVITY	NACH R1200	NACH R 2000	HEALTH DEP
3.1	2.8047166	0.97781247	0.9617129	-2.1
0	2.9580764	0.93158105	0.90552619	-1.5
5.1	3.1004028	1.0842518	1.1156285	-1.4
4.7	3.1669416	1.1458796	1.0905735	-1.8
0	2.97010455	1.0263359	1.0004313	-1.6
3.9	3.1157501	1.03757125	1.02440695	-1.5
0	2.9794698	0.99619341	0.95513433	-1.2
25.4	2.1899452	0.97440243	0.96369988	-0.9
0	3.1418533	1.1897906	1.1530138	-1.3
4.3	2.9729393	1.1115844	1.1829329	-0.9
9.4	3.3971481	1.032908287	1.071741156	-0.9
0	2.7761819	1.0878148	1.0907557	-1.3
0	2.7117877	0.90602052	0.91719174	-1.2
9.4	2.63212585	1.001321895	0.94918537	-1.3
9.4	2.9054416	1.18809005	1.21095295	-0.9
17.6	2.729326436	1.1574296	1.14198485	-0.7
0	2.96131885	1.0449818	1.04246255	-0.3
19.2	2.733277549	0.9857704	0.96382397	-0.1
38.6	3.0549154	0.98362398	0.95172465	-0.5
27.8	2.03462495	0.97334805	0.9804239	-0.1
33.3	2.9666846	0.96181375	0.96869689	-0.5
12.4	3.2042596	1.0288584	0.99845439	-0.5
1.8	4	1.1055143	1.0620855	-0.6
4.8	2.6370709	1.0804676	1.0704079	0.3
47.5	2.9084682	1.1758204	1.2180727	0.5
31.6	2.15916085	0.499766785	0.479948862	0.6
58.3	2.4324307	0.914219555	0.88473177	0.6
43.1	2.9948926	0.96990627	0.9486289	0.5
28.1	2	0.95129475	0.904253365	0.4
9	3.00458835	1.0534078	1.03368765	-1.5
10.2	3.0741017	1.0324779	1.0148057	-0.9
26.6	2.98477865	0.936123635	0.949677615	-0.4
16.3	2.98626625	1.00449845	0.975450395	-0.2
21	3.1856389	1.02056035	0.995671985	0.5

Table 7: Values exported from geospatial data that shows the values Residential density, angular connectivity, NACH R1200, NACH R 2000 and Health deprivation values for regions 1-34 respectively. The values for NACH and Angular connectivity are a median of total values for the entire LSOA unit since median is a more accurate measure of central tendency.

4.13 CHECKING CORRELATION

Given below are the correlation value summaries of Health deprivation and independent variables- Residential density, angular connectivity, NACH R1200 and NACH R 2000 (Table 8). Each correlation with health deprivation is negative except residential density that has a strong positive correlation with health deprivation.

Correlations

		HEALTH DATA	RESIDENTIAL DENSITY
Pearson Correlation	HEALTH DATA	1.000	.731
	RESIDENTIAL DENSITY	.731	1.000
Sig. (1-tailed)	HEALTH DATA	.	.000
	RESIDENTIAL DENSITY	.000	.
N	HEALTH DATA	34	34
	RESIDENTIAL DENSITY	34	34

		HEALTH DATA	NACH_R1200
Pearson Correlation	HEALTH DATA	1.000	-.325
	NACH_R1200	-.325	1.000
Sig. (1-tailed)	HEALTH DATA	.	.030
	NACH_R1200	.030	.
N	HEALTH DATA	34	34
	NACH_R1200	34	34

		HEALTH DATA	ANGULAR CONNECTIVITY
Pearson Correlation	HEALTH DATA	1.000	-.321
	ANGULAR CONNECTIVITY	-.321	1.000
Sig. (1-tailed)	HEALTH DATA	.	.032
	ANGULAR CONNECTIVITY	.032	.
N	HEALTH DATA	34	34
	ANGULAR CONNECTIVITY	34	34

		HEALTH DATA	NACH_R2000
Pearson Correlation	HEALTH DATA	1.000	-.297
	NACH_R2000	-.297	1.000
Sig. (1-tailed)	HEALTH DATA	.	.044
	NACH_R2000	.044	.
N	HEALTH DATA	34	34
	NACH_R2000	34	34

Table 8: The correlation values between Health deprivation and each independent variable mentioned on the right-hand column

5 CONCLUSIONS

5.1 MODEL SUMMARY

Based on the results of the regression analysis, an equation is obtained that can predict the value of health (x) if the values of y and c are known- y being the independent variable that has correlation with x and c is a constant. This can help us predict the health deprivation levels for the model when independent variables values are known (Table 9).

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.731[a]	.535	.520	.5310271460	.535	36.777	1	32	.000

a. Predictors: (Constant), RESIDENTIAL DENSITY

b. Dependent Variable: HEALTH DATA

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.321[a]	.103	.075	.7372640565	.103	3.680	1	32	.064

a. Predictors: (Constant), ANGULAR CONNECTIVITY

b. Dependent Variable: HEALTH DATA

Table 9: Model summaries for Health deprivation and Residential density and angular connectivity

R Square and Adjusted R Square values indicate the amount of variation in dependant variable explained by the independent variable. Out of all the variables only residential density explains the most amount of variation (~50%) in Health Deprivation. The model indicates that the by 1 unit change in Residential density increases Health deprivation by an average of 0.035 units. h. Residential density has the highest Pearson's correlation through mean (Figure 9).

Figure 9: Mean values calculated for the independent variable Residential density against Health deprivations for regions 1-34.

5.2 OVERVIEW

From segment map, catchment and metric step analysis: Areas of high integration and choice have a local or pocket park within the neighbourhood they border. Highly Integrated streets contain social infrastructure, lesser within study area as compared to centre. Access to social infrastructure along highly integrated streets with north and south wards lacking in comparison to central wards. Availability ratio: It is seen that regions in red (high deprivation) near Belsize Park have almost no open and green spaces while

regions in blue (low deprivation) have higher values of open and green spaces, as well as social infrastructure values. Small deficiencies of access to open and green spaces along Haverstock hill in Gospel Oak (east end) and edge of Kentish Town's west end. Large deficiencies towards south-west edge of Hampstead town and Swiss cottage. These results of linear regression indicate: Out of the selected independent variables only residential density has a strong and positive Pearson's Correlation value (0.731) and the corresponding P value of .000 indicates that this correlation is also statistically significant. Angular connectivity, NACH R1200 and NACH R2000 show moderate negative correlations.

Health depreciation is studied to identify direct impacts of the surrounding areas in Camden. It is understood that the extent of impact of the health developments is limited to walking distance from the parks and the local communities have no data on extensive health benefits since no significant correlation was found. However, catering to people living in social housing units, particularly in the deprived areas with improved availability and accessibility to open green spaces and social infrastructure can improve health levels. For radii up to 1200m-2000m from the park, it can be said with certainty that the health of residents has increased closest to the park and decreases as one moves away. There are deficiencies in both Study regions where not all residents have access to Metropolitan parks within 3200 m from home, district parks within 1200m and pocket parks within 400 m from home. There is no significant advantage of living closer to a metropolitan park versus a local park. Study area 1 has two major metropolitan parks around it and one within the region, while study area 2 has no metropolitan park closer to it, but the health values of study area 2 show less deprived outcomes. Thus, it is advantageous to have any green or open space around. The limitation however is that the area chosen and the sample size for health deprivation values are lesser than Study area 1 in Study area 2, thus a perfect comparison is invalid. Though many people use open and green spaces for health benefits, the access to a holistic combination of open-green and social infrastructure within a region could contribute to healthier, inclusive communities.

The main takeaway from the study in order to further explore implementations of policies regarding green and open space is to apply more evidence-based design solutions that capture the patterns generated by space and how it is used by people. On a local level, site observations of usage of open and green spaces, the access around them and the level of public activities can produce interesting interrelated results. These characteristics acknowledge the interdependence between design and space that formats a relationship or an emergent process of well-used and accessible of green and open spaces with a good availability ratio. It will convert as an advantage that includes evidence and analytical based approaches to design and policy making it unbiased to any impulsive planning interventions.

5.3 LIMITATIONS

Sometimes, use of space cannot be attributed to just spatial variables, a lot of social and psychological factors like motivation, personal tastes and other local and global phenomena like bad weather and Pandemics like Covid-19 restrain the use of green or open spaces. Sometimes, even the time of day maybe a factor. Other limitations of the study are data used are self-reported values with only about 60-70% population without the understanding of any specific parameters influencing health. Use of space, also had to only be done through literature available and Gate counts were not permitted during Covid-19.

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